The Preliminary Study on Juvenile-Mature Correlation of *Pinus Koraiensis*

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Abstract: Through studying seven analytic trees from two stands of *Pinus koraiensis* artificial forests. the results show that the individual variation coefficient of tree height. dbh and volume decreases with age increasing after age of 25. Age of 25 is the age that difference of individual growth is from acute difference to comparatively stability. The optimum selection age is 25a for *Pinus koraiensis*'s artificial forests according to the analysis of juvenile-mature correlation. and early selection efficiency.

Key words: *Pinus koraiensis*; Juvenile-Mature Correlation: Early selection

Introduction

Wood is very important final product in forest management, and improving wood product and quality are common goal in most breeding systems. Early selection for tree growth not only provide excellent nursery store material for planting high yield forest, but also possibly improve selection efficiency, shorten breeding period. So studying early selection of tree growth is important meaning for forestry product and tree variety development.

Pinus koraiensis is important commercial tree species in north of China. It has excellent wood quality and distinctive economic value. Because of unreasonable falling and backward in management technology in recent hundreds of years, store area of *Pinus koraiensis* forest have reduced, and reserve resource is serious insufficient. For this situation, how to recover and develop well *Pinus koraiensis* forest must be considered in forestry. Practice has proved that improving product and quality of *Pinus koraiensis* forest through genetic improvement is a feasible way. Early selection is essential base for genetic improvement of *Pinus koraiensis*.

In this paper, our aim is to decide suitable age for early selection and select suitable appraisal age for genetic improvement test of *Pinus koraiensis*.

Materials and Methods

Experiment materials and sampling method

The materials came from mature and man-planted forest of *Pinus koraiensis* in Experiment Forest Farm of Forest Management and Research Institute, Liaoning Province. For raising representation of experiment result, two stands were selected. The age of first one is 60 years old, ground slope is 25°; the other is 62 years old, ground slope is 15°. Two of stands had enough forest density and their hygienic condition are good. The selected sample tree is dormant tree growing normally, which the interval distance is at least 50 meters.

Four sample trees were respectively selected from the two stands for studying juvenile-mature correlation. The sample trees were fallen very closely to ground and trees trunk were cut out as disks every 2 m. Tree analysis was conducted taking five years as a age-gradation. Tree height, dbh (breast height diameter) and volume were calculated at age of 5, 10,... 60, according to the results of tree analysis. Through comparatively studying growth curve of tree height, dbh and volume, the results show that tree growth law of two stands is very similar. Thus, analytic trees from the two stands were combined into one sample to be analyzed.

Statistical analysis method

According to analytic tree materials, we calculate coefficients of variation of tree height, dbh (breast height diameter) and volume at different age for early selection. There are different C.V. (sample standard deviation/mean) and variation extent by different age. We can find the stability age of growth from surface plots. Based on this, variation law of *Pinus koraiensis* growth was analysed.

The age of reaching significant correlation were de-

cided through Pearson's correlation (r) of juvenile-mature growth and variation trend of juvenile-mature growth correlation. Correlation law of early selection was estimated using the formula $E = r_{pjm} \frac{T_m}{T_j}$

where: T_m is rotation falling age (60 years old in this study)

T_j is early selection age

r_{pjm} is a correlation coefficient calculated by regression equation on juvenile-mature correlation with age.

Results and Analysis

Individual variation of *Pinus koraiensis* growth

Variation coefficients (Table 1) of tree height, dbh and volume were calculated according to the C.V. formula, and the variation curve (Fig. 1) was drawn. The results show that variation coefficients of tree height, dbh and volume have similar variation trend. Their coefficients of variation were all higher at young age (under age of 25), but gradually decreased with age increasing. Variation coefficients decreased quickly before 25 years old and tended to stability after age of 25. This is probably because competition among different individuals was more fierce, and growth variation of individual was great before age of 25. The competition tended to stability after 25 years old. This showed that the age of 25 was turning point that the difference of individual growth variation coefficients was from acute differentiation to relatively stability.

The variation coefficients of volume is higher than that of dbh (From Fig. 1), and dbh variation coefficients was higher than that of tree height. This showed that variation coefficients of tree height was more stable than that of dbh, it fitted to be used as index of early selection.

Table 1. The coefficients of variation about tree height, dbh and volume at different age

Age	Tree height		dbh		Volume	
	Mean	Coefficients of variation	Mean	Coefficients of variation	Mean	Coefficients of variation
5	1.608	0.4170	0.564	1.8417	0.00054	1.4752
10	4.057	0.2523	4.493	0.5465	0.00560	0.9875
15	6.981	0.1514	8.821	0.2325	0.02363	0.5631
20	9.886	0.0932	12.757	0.1290	0.06429	0.3308
25	12.343	0.0660	16.250	0.0839	0.12703	0.2104
30	14.500	0.0483	18.479	0.0909	0.19637	0.1912
35	16.601	0.0451	20.150	0.0881	0.27117	0.1954
40	18.233	0.0463	22.527	0.0885	0.36307	0.1787
45	19.602	0.0431	25.016	0.0868	0.45789	0.1754
50	20.962	0.0408	27.159	0.0917	0.56389	0.1680
55	22.326	0.0434	29.179	0.1153	0.68260	0.2000054
60	23.439	0.0473	31.049	0.1308	0.80646	0.2248

Table 2. Juvenile-mature correlation coefficient(r) and selection efficiency(E) of tree height, dbh and volume

Age	Tree height-tree height		dbh-dbh		Volume-volume		dbh-volume	
	r	E	r	E	r	E	r	E
5	0.6000	6.32	0.1176	0.40	-0.0250	0.68	0.1644	0.92
10	0.5968	3.32	0.1206	1.05	0.0283	0.53	0.1310	1.05
15	0.6228	2.41	0.1679	1.33	0.0968	1.00	0.1134	1.23
20	0.6170	2.00	0.5072	1.49	0.4092	1.24	0.4694	1.37
25	0.7688*	1.78	0.7793*	1.57	0.7624*	1.38	0.7554*	1.47
30	0.7688*	1.64	0.8837**	1.60	0.7745*	1.45	0.8577*	1.52
35	0.9208**	1.52	0.9272**	1.57	0.8159*	1.46	0.9013**	1.53
40	0.9665**	1.42	0.9525**	1.50	0.9026**	1.42	0.9403**	1.48
45	0.9910**	1.32	0.9654**	1.39	0.9666**	1.34	0.9379**	1.37
50	0.9907**	1.21	0.9957**	1.23	0.9942**	1.21	0.9807**	1.22
55	0.9891**	1.08	0.9980**	1.03	0.9993**	1.05	0.9887**	1.01

Note: The dbh and volume before "-" stand for early traits, and those after "-" stand for traits at age of 60.

Juvenile-mature correlation of growth variation

The age of 60 (the oldest age that all analytic trees can reach) was taken as mature age to calculate the Pearson's correlation between the early growth character and the mature character, and the results were listed in Table 2. Then the trend surface plot about the correlation coefficients' change at different age was drawn in Fig. 2.

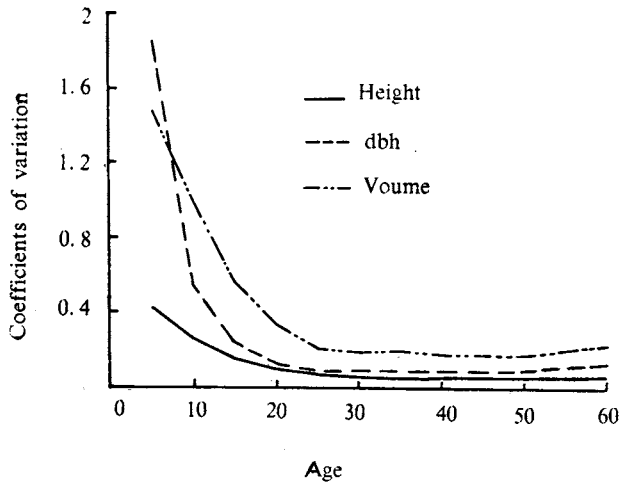

Fig. 1. The curve of variation coefficientients

From Fig. 2, four kinds of C.V. have similar variation rules. Correlation coefficients are small at young age, and increased with age increasing. They increased quickly before age of 25, but at old age, they increased slowly. But the trees tend to be stable after 30 years old. Table 2 showed that four kinds of correlation coefficients all reached significant level at age 25. This showed that early selection for planted forest of *Pinus koraiensis* is reliable after age of 25.

Selection efficiency and optimum selection age

Selection efficiency is the ratio of the genetic effect between before the rotation falling age and at mature age, and the ratio can reflect the results of selection. For calculating selection efficiency, regression equation on correlation coefficient and ratio of age (young age / mature age) was fitted. Based on this, theoretical value of correlation coefficient was calculated.

In general, simple regression between the natural logarithm of age ratio and correlation coefficient was applied in most published literature's. But sometimes this method really can't show their relations. We select the forms of regression equation between them. The results showed that the R^2 of cubic mutilnomial equation is the biggest (Listed in Table 3). According to this equation, theoretical correlation and selection efficiency (listed in Table 2) were calculated at different age. The curve (Fig. 3) was drawn using these values. The selection efficiency of tree height acutely dropped at young age from Fig. 3. At age of 20~25, this trend become slow, selection efficiency of dbh is small at young age and gradually become great with age increasing before age of 25. It reached the greatest value at age 25 and become slow after age of 25. So, the age of 25 is suitable age for early selection on basis of selection efficiency.

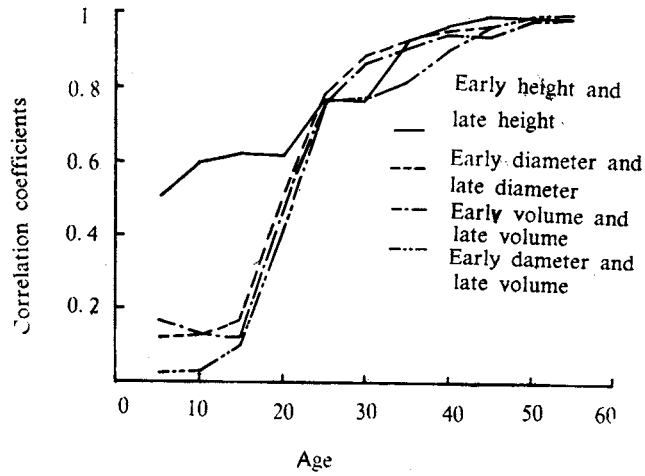

Fig. 2. The curve of crrelation coefficients

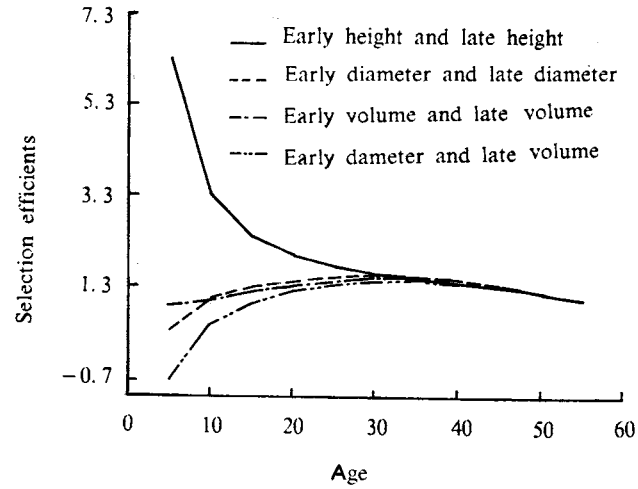

Fig. 3. The curve of selection efficiency

Comprehensively considered three indexes (variation coefficient, correlation coefficient and selection efficiency), we think that the age of 25 is optimum age for selection of *Pinus koraiensis* planted forest in the area

of Caohekou, Liaoning Province.

Table 3. Regression equations of juvenile-mature correlation coefficient among growth characters

Traits	Regression equations	R^2	F value
Tree height-tree height	$0.5295-0.2424x+2.6370x^2-1.9949x^3$	0.970	75.948**
dbh-dbh	$-0.0826+1.1968x+2.5903x^2-2.9192x^3$	0.948	42.547**
Volume-volume	$-0.1785+1.2855x+2.3534x^2-2.6189x^3$	0.951	45.596**
dbh-volume	$0.0236+0.3101x+4.2566x^2-4.8430x^3$	0.932	31.981**

Note: The dbh and volume before "-" stand for early traits, and those after "-" stand for traits at age of 60

Conclusions

The individual variation coefficient of tree height, dbh and volume for *Pinus koraiensis*' artificial forests decrease with age increasing after age of 25. Age of 25 is the age that variation of coefficient of individual growth is from acute difference to comparatively stability.

The optimum selection age is 25a for *Pinus koraiensis*'s artificial forests according to the analysis of juvenile-mature correlation and early selection efficiency.

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